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ENVIRONMENTAL EXPOSURE EFFECTS ON COMPOSITE MATERIALS FOR COMMERCIAL AIRCRAFT

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HAMPTON, VIRGINIA 23665

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by

THE BOEING COMMERCIAL AIRPLANE COMPANY

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FOREWORD

This report was prepared by the Boeing Commercial Airplane Company, Seattle, Washington, under Contract NAS1-15148. It is the tenth quarterly technical progress report covering work performed between 1 December 1980 and 28 February 1981. The program is sponsored by the National Aeronautics and Space Administration, Langley Research Center. Mr. Andrew J. Chapman and Mr. Ronald K. Clark are the NASA Technical Representatives.

This contract is being performed by the Advanced Structural Concepts organization. Key personnel associated with the program during the reporting period and their area of responsibility are:

J. E. McCarty	--Program Manager
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1.0 SUMMARY AND PROGRAM STATUS

This period's activities were highlighted by continued long term and accelerated lab exposure testing, and by completion of all fabrication tasks on the optional material systems, AS1/3501-6 and Kevlar 49/Fi61-188. Initial baseline testing was performed on the two optional material systems.

Long term exposure specimens have now been returned from three of the four ground rack sites and from two of the three aircraft locations. Test data from specimens returned from Dryden after 2 years exposure do not indicate continuing trends of strength reduction from the 1 year data. Test data from specimens returned from the Wellington, New Zealand ground rack and on Air New Zealand aricraft after 1 year exposure show strength changes fairly typical of other locations.

Additional accelerated laboratory test data has also been collected including 2 Year Time Alone, 1 Year Weatherometer, and 6 Month Ground-Air-Ground Cycling.

Activities during the next quarter will include receipt and test of: Honolulu 2 year ground rack specimens, Aloha Airlines 2 year flight specimens, Dallas 1 year ground rack specimens, and Southwest Airlines 1 year flight specimens. Initial deployment should also occur for the optional material long term specimens.

2.0 INTRODUCTION

The introduction of any new material system into commercial aircraft structure requires that an information data base be available to the designer in such a form that he can accept the material as a viable alternate to the current material system in use. Composite material components on aircraft in scheduled commercial service have demonstrated a viable level of confidence in current design and fabrication methods. In spite of this, the long term durability of composites exposed to actual aircraft operational environments represents a significant unknown in assessing the risk level for a production commitment to primary aircraft structure.

This contract will focus on expanding the data base for composite materials' properties as they are affected by the environments encountered in operating conditions, both in flight and at ground terminals. It is well known that absorbed moisture will degrade the mechanical properties of graphite/epoxy laminates at elevated temperatures. Since aircraft components are frequently exposed to atomospheric moisture, rain, and accumulated water, quantitive data are required showing the amount of fluids absorbed under various environmental conditions. In addition, accelerated laboratory test techniques must be developed that are reliably capable of predicting long term behavior. The study will include a task to develop an accelerated environmental exposure testing procedure and to correlate all experimental results and compare with analytical results to establish the level of confidence for predicting composite material properties.

The overall program has a duration of approximately 11 years and is performed in three tasks as follows:

- Task I - Flight Exposure
- Task II - Ground Based Exposure
- Task III - Accelerated Environmental Effects and Data Correlation

Among the parameters to be investigated are: geographic location, flight profiles, solar heating effects, ultraviolet degradation, retrieval times, specimen types, test temperatures, and others. The experimental program includes in-flight and ground exposures of up to 10 years and will obtain mechanical, physical, and chemical data from about 17,000 specimens. A complete description of the program content was given in the first Quarterly Report (Reference 1). Other reports (References 2-9) have covered progress to date. The overall program is summarized schematically in Figure 2-1. The program schedule is shown in Figure 2-2.

ENVIRONMENTAL EXPOSURE EFFECTS ON COMPOSITE MATERIALS FOR COMMERICAL TRANSPORT AIRCRAFT

- FIVE MATERIAL SYSTEMS
- LONG TERM GROUND & FLIGHT EXPOSURE DATA
- ACCELERATED LABORATORY DATA
- DURABILITY MODEL & ACCELERATED TEST PROCEDURES

TASK I FLIGHT EXPOSURE

- CONFIDENCE THROUGH LONG TERM EXPOSURE DATA
- INTERIOR AND EXTERIOR EXPOSURE ON THREE DIFFERENT AIRLINES FOR TIMES UP TO TEN YEARS
- OVER 5300 SPECIMENS

TASK II GROUND EXPOSURE

- CONFIDENCE THROUGH LONG TERM EXPOSURE DATA
- SOLAR AND NONSOLAR EXPOSURE AT FOUR DIFFERENT GROUND STATIONS FOR TIMES UP TO TEN YEARS
- OVER 5300 SPECIMENS

TASK III ACCELERATED ENVIRONMENTAL EFFECTS AND DATA CORRELATION

- BASELINE TESTING
- ACCELERATED TESTS TO LOOK AT THE EFFECTS OF TIME, TEMPERATURE, STRESS, MOISTURE, WEATHEROMETER, AND GROUND-AIR-GROUND SIMULATION
- OVER 4300 SPECIMENS
- ANALYTICAL MODEL FOR DURABILITY PREDICTION
- RECOMMENDED ACCELERATED TEST PROCEDURES FOR EVALUATING ENVIRONMENTAL RESISTANCE

Figure 2-1. Program Content

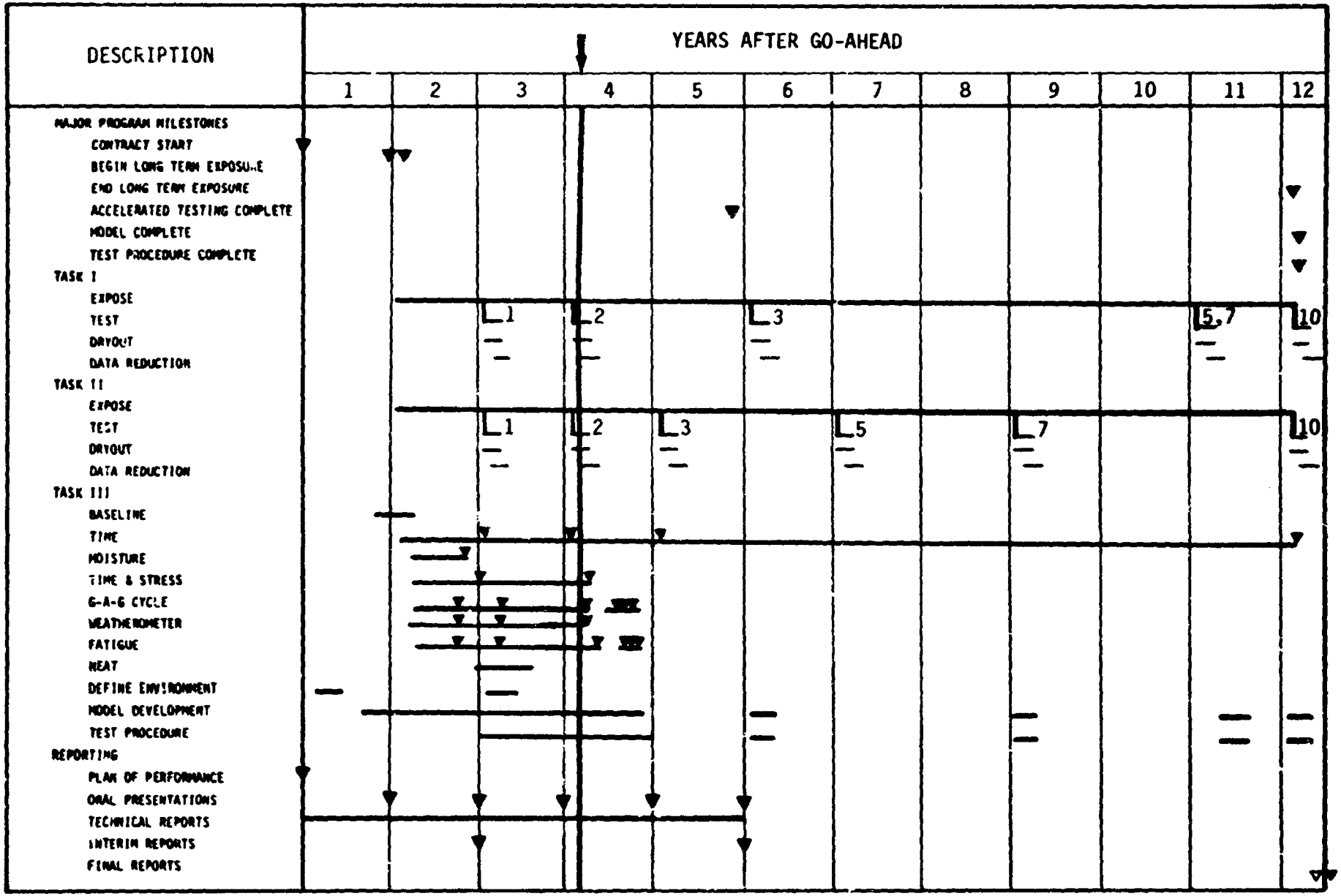

Figure 2-2. Program Schedule

3.0 DESIGN

No tasks currently active.

4.0 FABRICATION

During the original fabrication effort of AS1/3501-6 specimens, a short fall in finished flexure and zero degree compression specimens was experienced. Since the original batch of material was believed to be exhausted, another batch of material was ordered to make up the deficiency. Receiving inspection was performed according to BMS 8-212, and results appear in Table 4-1. In the mean time, a quantity of the original material batch was found and the amount was determined to be sufficient to fabricate the needed number of flexure specimens. Therefore, one panel was fabricated from the new batch for compression specimens, and one panel was fabricated from tne original batch for flexure specimens.

Remaining tasks on the optional material specimen fabrication are: final weights for the 49/F161-188 tension specimens, and dimensions and painting of the make-up AS1/3501-6 compression specimens.

Fabrication of the stressed tension specimen fixtures has begun. Two hundred nine feet of 2 inch O.D. titanium tubing has been received sufficient to fabricate 230 tension tubes. Fabrication of other hardware associated with the tension tubes has also begun.

Table 4-1 AS1/3501-6, Receiving Inspection Data (Second Batch)

RECEIVING INSPECTION TEST RESULTS PER BMS 8-212 (1)

SUPPLIER AND MATERIAL HERCULES AS1/3501-6

TYPE 1 CLASS 1 GRADE 145 BATCH/ROLL 1734/20A

DATE OF MANUFACTURE 11-8-90 DATE OF RECEIPT 12-1-90

PREPREG PHYSICAL PROPERTIES

PROPERTY	RESULTS					
	INDIVIDUAL TEST NUMBER					
	1	2	3	4	5	AVERAGE
Areal Weight Graphite Only gm/m^2	153.00	152.00	157.00			154.00
Resin Content, Percent Weight	40.99	44.11	42.42			42.50
Volatiles Content, Percent Weight	.92	.90	.93			.92
Flow, Percent Weight	26.26	25.71	26.15			26.00
Gel Time, Minutes	(2)					
Tack						PASS

LAMINATE PHYSICAL AND MECHANICAL PROPERTIES

PROPERTY		RESULTS					
		INDIVIDUAL TEST NUMBER					
		1	2	3	4	5	AVERAGE
Ply Thickness, mils		5.47 (3)	5.40 (3)				5.40
Fiber Volume, percent							TBD
Void Content							PASS
0° Short Beam Shear Strength, ksi	-65°F	19.12	19.45	20.30	19.56	15.21	18.70
	RT	15.48	14.78	15.67	15.58	16.24	15.50
	270°F	9.67	9.61	9.99	9.88	9.09	9.60
0° Tensile Strength, ksi	RT	183.50	206.10	218.00	246.20	256.10	232.00
0° Tensile Modulus, msi	RT	17.14	18.07	17.09	16.05	18.10	17.40
±45° Tensile Strength	-65°F	(2)					
	RT	(2)					

NOTES

(1) Specification Modified Slightly for Non Qualified System

(2) This Test No Longer Required for Receiving Inspection

(3) Average of 6 Readings

5.0 TEST

Progress in the area of test during this reporting period was highlighted by continued Task I, Task II and Task III post exposure residual strength testing. Exposures for all three tasks are continuing.

5.1 LONG TERM EXPOSURE AND TESTING

Nominal two year ground rack specimens were withdrawn from Dryden Flight Research Center and returned to Boeing on October 14, 1980, nominal one year ground rack specimens were withdrawn from Wellington, New Zealand and returned on November 24, 1980, and nominal one year flight specimens were withdrawn from Air New Zealand aircraft number ZKNAJ and returned on November 25, 1980. Receipt of the two year exposure specimens from Honolulu and Aloha Airlines is expected soon. A summary of the long term specimen exposure status is shown in Table 5-1.

All received specimens, fixtures, and panels had a moderate to fairly heavy surface dust film. Items heavily coated with dust were photographed as received. Figure 5-1 shows a non-solar 2 year exposure panel from from Dryden. Surface cleaning was accomplished primarily with a dry cloth occasionally dampened with methel-ethel-keytone (MEK). Exterior flight specimens from Air New Zealand were covered fairly heavily with carbon dust (shown in Figure 5-2) which was completely removed to visual inspection with the MEK. After thorough cleaning, shear exposure, flexure, and tension specimens were removed from the fixtures and weighted on a Mettler analytic balance to an accuracy of 0.7 mg. Flexure and tension specimens were submitted directly to test. Compression specimens were stored in sealed containers until they could be tested in the Celanese compression fixture. Shear exposure specimens were cut into three short beam shear specimens each, and these were submitted to test. Shear exposure dryout specimens were placed in a 160^{0}F dryout oven for the standard 90 day dryout period.

Physical and mechanical property test results are shown in Tables 5-2 to 5-8. All values shown are for a single specimen except for the shear exposure (SE) specimens which are an average of 3 SBS specimens as described in the preceeding paragraph. Summaries of the strength and weight change data appear in Tables 5-9 to 5-15. The strength results generally represent the average of 3 speicmens each, and the weigh change is the average measurements of all specimens of a particular configuration. An exception is found in Table 5-9 for 5208 room temperature +45 tension specimens. A test machine malfunction caused the data to be lost for one of these specimens, so the reported strength is the average of two tests.

Table 5-1. Long Term Specimen Exposure Data

SERIES NAME	INSTALLATION DATE	ESTIMATED EXPOSURE AS OF FEBRUARY 28, 1981 [3]		
		CALENDAR TIME	FLIGHT HOURS	FLIGHT CYCLES
Task I				
Aloha - 3 Year	3-14-80	351	1642	4490
Aloha - 2 Year	2-14-79	745	3716	11036
Aloha - 10 Year	2-16-79	743	TBD [4]	TBD
ANZ - 3 Year	1-15-81	44	195	266
ANZ - 2 Year	8-15-79	563	3148	4298
ANZ - 10 Year	7-2-79	607	3321	4581
Southwest - 1 Year	2-15-80 [1]	379	3594	4766
Southwest - 2 Year	2-27-80	367	3520	4852
Southwest - 10 Year	6-22-80	251	2414	3246
Task II				
NASA Dryden	12-6-78 [2]	755		
Honolulu	2-9-79	689		
Wellington	7-4-79	545		
Dallas	4-18-80	316		

[1] Median date for installation of exterior and interior specimens.

[2] Rack Stored in Unheated Warehouse at Hugh L. Dryden Flight Research Center from 10-30-79 to Date of Installation.

[3] Flight data based on Actuals through February 28, 1981 and Historical Utilization Data.

[4] Specimens transferred to second aircraft due to sale of initial aircraft.

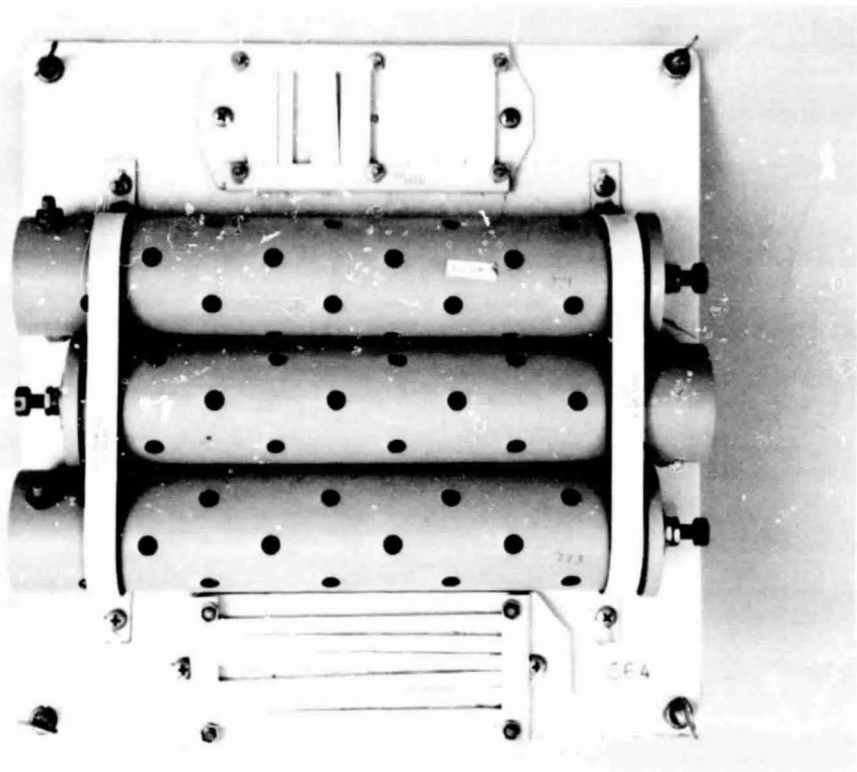

Figure 5-1. Dryden, 2 Year Ground Exposure Panel, Non-Solar

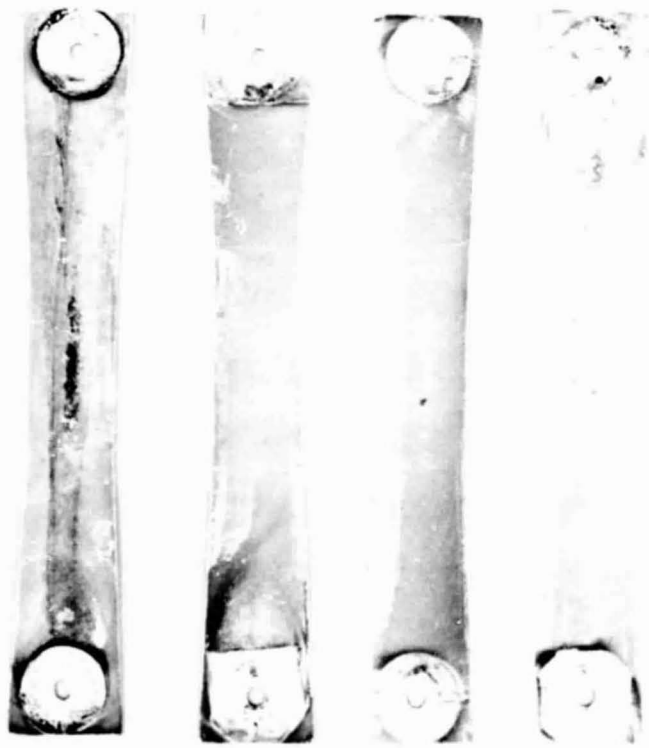

Figure 5-2. Air New Zealand 1 Year Flight Exposure, Non-Solar Tension Specimens

Table 5-2 Physical and Mechanical Test Results, Dryden 2 Year Solar Specimens

IDENTIFYING CHARACTERS		LAMINATE THICKNESS (IN)	LAMINATE WIDTH (IN)	INITIAL DRY LAMINATE WEIGHT (GRAM)	INITIAL DRY SPECIMEN WEIGHT (GRAM)	EXPOSED SPECIMEN WEIGHT (GRAM)	FINAL DRY SPECIMEN WEIGHT (GRAM)	ULTIMATE FAILURE LOAD (POUND)	TEST TEMPERATURE (F)
ASEES02	1	.0975	.2519	1.3564	1.5177	1.5176		521.00	70.0
ASEES02	2	.0977	.2472	1.3286	1.4770	1.4773		415.30	180.0
AFLES02	1	.0663	.4993	1.7552	2.0144	2.0095		153.25	70.0
AFLES02	2	.0660	.4989	1.7708	2.0325	2.0254		146.00	70.0
AFLES02	3	.0672	.4961	1.7793	2.0456	2.0406		153.75	70.0
AFLES02	4	.0668	.4963	1.7497	2.0206	2.0130		148.75	180.0
AFLES02	5	.0664	.4943	1.7512	2.0137	2.0093		137.25	180.0
AFLES02	6	.0664	.4973	1.7655	2.0387	2.0339		135.75	180.0
AT4ES02	1	.0423	1.0035	9.0384	10.8829	10.8446			70.0
AT4ES02	2	.0428	1.0027	9.0554	10.8648	10.8375		1095.00	70.0
AT4ES02	3	.0428	1.0028	9.0899	11.0018	10.9634		1112.00	70.0
AT4ES02	4	.0437	.9983	8.9569	10.7471	10.7059		818.00	180.0
AT4ES02	5	.0430	.9987	9.0431	10.8177	10.7869		800.00	180.0
AT4ES02	6	.0428	.9987	8.9417	10.8690	10.8375		822.00	180.0
BSEES02	1	.1026	.2469	1.3632	1.5004	1.5008		421.70	70.0
BSEES02	2	.1034	.2450	1.3778	1.5185	1.5184		271.30	180.0
BFLES02	1	.0633	.4975	1.6739	1.9800	1.9731		142.75	70.0
BFLES02	2	.0640	.4955	1.6782	1.9812	1.9558		144.75	70.0
BFLESC2	3	.0630	.4954	1.6637	1.9812	1.9542		138.50	70.0
BFLES02	4	.0640	.4960	1.6648	1.9631	1.9571		95.75	180.0
BFLES02	5	.0635	.4945	1.6699	1.9889	1.9816		109.25	180.0
BFLES02	6	.0638	.4930	1.6664	1.9647	1.9585		98.25	180.0
BT4ES02	1	.0463	1.0021	9.7933	11.6670	11.6394		1355.00	70.0
BT4ES02	2	.0467	1.0042	9.7934	11.6205	11.5924		1320.00	70.0
BT4ES02	3	.0465	.9942	9.5240	11.1909	11.1691		1286.00	70.0
BT4ES02	4	.0455	.9947	9.5605	11.3290	11.3050		1030.00	180.0
BT4ES02	5	.0461	.9970	9.5757	11.5163	11.4885		1208.00	180.0
BT4ES02	6	.0460	1.0020	9.6131	11.5443	11.5162		1080.00	180.0
CSEES02	1	.1091	.2487	1.4908	1.6297	1.3614		519.70	70.0
CSEES02	2	.1109	.2477	1.4870	1.6540	1.6547		394.30	180.0
CFLES02	1	.0673	.5010	1.8184	2.0830	2.0783		159.00	70.0
CFLES02	2	.0649	.4982	1.7281	2.0085	2.0034		137.00	70.0
CFLES02	3	.0660	.4986	1.7992	2.0916	2.0867		149.00	70.0
CFLES02	4	.0641	.4959	1.6900	1.9756	1.9701		123.00	180.0
CFLES02	5	.0665	.5004	1.7672	2.0525	2.0462		146.00	180.0
CFLES02	6	.0676	.4984	1.8044	2.0749	2.0711		150.00	180.0
CT4ES02	1	.0466	1.0011	9.8827	11.8297	11.8082		1187.00	70.0
CT4ES02	2	.0462	1.0032	9.9379	11.9754	11.9490		1183.00	70.0
CT4ES02	3	.0475	1.0022	9.9117	11.9117	11.8838		1194.00	70.0
CT4ES02	4	.0465	1.0006	9.8017	11.7662	11.7369		1060.00	180.0
CT4ES02	5	.0466	1.0023	9.8129	11.7443	11.7185		1060.00	180.0
CT4ES02	6	.0474	1.0041	9.8744	11.9102	11.8825		1010.00	180.0

Table 5-3 Physical and Mechanical Test Results, Dryden 2 Year Non-Solar Specimens

IDENTIFYING CHARACTERS	LAMINATE THICKNESS (IN)	LAMINATE WIDTH (IN)	INITIAL DRY LAMINATE WEIGHT (GRAM)	INITIAL DRY SPECIMEN WEIGHT (GRAM)	EXPOSED SPECIMEN WEIGHT (GRAM)	FINAL DRY SPECIMEN WEIGHT (GRAM)	ULTIMATE FAILURE LOAD (POUND)	TEST TEMPERATURE (F)
ASEEN02 1	.0969	.2463	1.3008	1.4585	1.4600		458.00	70.0
ASEEN02 2	.0977	.2497	1.3256	1.4818	1.4836		398.70	180.0
AFLEN02 1	.0659	.4971	1.7623	2.0603	2.0435		141.75	70.0
AFLEN02 2	.0672	.4977	1.7667	2.0510	2.0488		144.75	70.0
AFLEN02 3	.0661	.4996	1.7557	2.0531	2.0471		142.25	70.0
AFLEN02 4	.0665	.4983	1.7822	2.0655	2.0417		142.25	180.0
AFLEN02 5	.0666	.4945	1.7654	2.0438	2.0417		151.00	180.0
AFLEN02 6	.0671	.4961	1.7669	2.0512	2.0494		146.25	180.0
AT4EN02 1	.0454	.9988		26.0140	25.7742		1005.00	180.0
AT4EN02 2	.0456	.9985		25.7736	26.0410		925.00	180.0
AT4EN02 3	.0453	.9995		26.0476	26.0176		900.00	180.0
AC0EN02 1	.1000	.2453					6080.00	72.0
AC0EN02 2	.0997	.2485					5970.00	72.0
AC0EN02 3	.1031	.2470					4880.00	72.0
AC0EN02 4	.1054	.2473					3750.00	180.0
AC0EN02 5	.0994	.2459					4000.00	180.0
AC0EN02 6	.0992	.2373					3430.00	180.0
BSEEN02 1	.1045	.2500	1.3965	1.5633	1.5631		438.30	70.0
BSEEN02 2	.1038	.2495	1.3142	1.5966	1.5966		274.70	180.0
BFLEN02 1	.0632	.4970	1.6734	1.9829	1.9770		139.50	70.0
BFLEN02 2	.0631	.4930	1.6518	1.9697	1.9647		135.50	70.0
BFLEN02 3	.0631	.4940	1.6593	1.9737	1.9686		129.50	70.0
BFLEN02 4	.0631	.4950	1.6687	1.9671	1.9617		116.50	180.0
BFLEN02 5	.0640	.4942	1.6700	1.9744	1.9691		109.25	180.0
BFLEN02 6	.0635	.4960	1.6633	1.9532	1.9493		111.25	180.0
BT4EN02 1	.0430	1.0047		25.5920	25.5734		990.00	180.0
BT4EN02 2	.0441	1.0061		25.3711	25.3503		1040.00	180.0
BT4EN02 3	.0426	1.0017		25.5636	25.5416		980.00	180.0
BC0EN02 1	.1010	.2512					5890.00	72.0
BC0EN02 2	.1028	.2507					6320.00	72.0
BC0EN02 3	.1007	.2473					6160.00	72.0
BC0EN02 4	.1028	.2506					3800.00	180.0
BC0EN02 5	.1043	.2509					3830.00	180.0
BC0EN02 6	.1100	.2511					3750.00	180.0
CSEEN02 1	.1093	.2499	1.5053	1.6755	1.6770		530.30	70.0
CSEEN02 2	.1117	.2498	1.5261	1.7098	1.7120		400.30	180.0
CFLEN02 1	.0667	.4965	1.7706	2.0445	2.0413		187.50	70.0
CFLEN02 2	.0658	.4985	1.7460	2.0283	2.0239		149.00	70.0
CFLEN02 3	.0666	.4980	1.7638	2.0477	2.0440		139.25	70.0
CFLEN02 4	.0652	.4957	1.7498	2.0376	2.0334		145.50	180.0
CFLEN02 5	.0660	.4983	1.7578	2.0420	2.0384		140.50	180.0
CFLEN02 6	.0667	.4989	1.7837	2.0600	2.0565		145.25	180.0
CT4EN02 1	.0484	1.0031		26.4208	26.4121		1270.00	180.0
CT4EN02 2	.0471	1.0021		26.5422	26.5374		1240.00	180.0
CT4EN02 3	.0470	1.0027		26.1314	26.1319		1060.00	180.0
CC0EN02 1	.1055	.2529					6920.00	72.0
CC0EN02 2	.1054	.2509					6870.00	72.0
CC0EN02 3	.1048	.2516					6780.00	72.0
CC0EN02 4	.1046	.2507					4830.00	180.0
CC0EN02 5	.1026	.2513					5260.00	180.0
CC0EN02 6	.1069	.2515					5040.00	180.0

Table 5-4 Physical and Mechanical Test Results, Wellington 1 Year Solar Specimens

IDENTIFYING CHARACTERS	LAMINATE THICKNESS (IN)	LAMINATE WIDTH (IN)	INITIAL DRY LAMINATE WEIGHT (GRAM)	INITIAL DRY SPECIMEN WEIGHT (GRAM)	EXPOSED SPECIMEN WEIGHT (GRAM)	FINAL DRY SPECIMEN WEIGHT (GRAM)	ULTIMATE FAILURE LOAD (POUND)	TEST TEMPERATURE (F)
ASEDS01 1	.0993	.2527	1.3767	1.5050	1.5531		495.00	72.0
ASEDS01 2	.0990	.2487	1.2907	1.4802	1.4534		331.00	180.0
AFLDS01 1	.0678	.4972	1.7725	2.0339	2.0487		151.75	72.0
AFLDS01 2	.0661	.4990	1.7791	2.0452	2.0598		141.50	72.0
AFLDS01 3	.0653	.4979	1.7593	2.0206	2.0348		137.75	72.0
AFLDS01 4	.0653	.4975	1.7565	2.0199	2.0324		125.00	180.0
AFLDS01 5	.0672	.4978	1.7733	2.0373	2.0502		131.50	180.0
AFLDS01 6	.0658	.4960	1.7577	2.0242	2.0382		134.50	180.0
AT4DS01 1	.0453	.9995	9.6954	11.0837	11.1578		1145.00	72.0
AT4DS01 2	.0453	.9978	9.7009	11.0847	11.1570		1180.00	72.0
AT4DS01 3	.0452	1.0039	9.6179	11.0130	11.0798		1175.00	72.0
AT4DS01 4	.0453	1.0016	9.5807	11.0910	11.1614		1060.00	180.0
AT4DS01 5	.0450	1.0023	9.6779	11.3157	11.3832		1026.00	180.0
AT4DS01 6	.0457	1.0009	9.6080	11.2812	11.3590		1060.00	180.0
BSEDS01 1	.1026	.2460	1.3672	1.4990	1.5048		391.00	72.0
BSEDS01 2	.1038	.2494	1.4000	1.5355	1.5417		213.00	180.0
BFLDS01 1	.0635	.4918	1.6557	1.9104	1.9174		135.00	72.0
BFLDS01 2	.0640	.4912	1.6495	1.8695	1.8762		122.20	72.0
BFLDS01 3	.0635	.4955	1.6670	1.9094	1.9161		129.00	72.0
BFLDS01 4	.0628	.4872	1.6344	1.8872	1.8952		88.80	180.0
BFLDS01 5	.0640	.4929	1.6561	1.9095	1.9171		78.80	180.0
BFLDS01 6	.0638	.4894	1.6349	1.8787	1.8838		84.00	180.0
BT4DS01 1	.0432	.9993	9.3128	10.4765	10.5187		1300.00	72.0
BT4DS01 2	.0441	1.0005	9.3187	10.5702	10.6118		1268.00	72.0
BT4DS01 3	.0440	.9994	9.3061	10.4506	10.4895		1335.00	72.0
BT4DS01 4	.0439	1.0020	9.3400	10.5451	10.5855		990.00	180.0
BT4DS01 5	.0436	.9980	9.2884	10.3978	10.4386		1010.00	180.0
BT4DS01 6	.0439	1.0003	9.3108	10.4642	10.5060		990.00	180.0
CSEDS01 1	.1108	.2490	1.5225	1.6320	1.6917		514.00	72.0
CSEDS01 2	.1132	.2485	1.5483	1.6951	1.7037		350.00	180.0
CFLDS01 1	.0668	.5003	1.7998	2.0562	2.0665		162.20	72.0
CFLDS01 2	.0655	.5007	1.7998	2.0590	2.0702		156.20	72.0
CFLDS01 3	.0662	.4964	1.7709	2.0277	2.0374		148.20	72.0
CFLDS01 4	.0651	.4988	1.7570	2.0011	2.0130		119.50	180.0
CFLDS01 5	.0678	.4986	1.8116	2.0507	2.0637		124.20	180.0
CFLDS01 6	.0661	.4983	1.7872	2.0201	2.0323		130.20	180.0
CT4DS01 1	.0450	1.0028	9.9067	10.9061	10.9639		1315.00	72.0
CT4DS01 2	.0466	1.0010	10.0774	11.0796	11.1285		1250.00	72.0
CT4DS01 3	.0478	1.0003	10.1755	11.1898	11.2458		1270.00	72.0
CT4DS01 4	.0481	1.0000	10.2651	11.3259	11.3861		1230.00	180.0
CT4DS01 5	.0486	1.0012	10.2537	11.2976	11.3492		1195.00	180.0
CT4DS01 6	.0460	1.0023	9.8547	10.8833	10.9365		1180.00	180.0

Table 5-5 Physical and Mechanical Test Results, Wellington 1 Year Non-Solar Specimens

IDENTIFYING CHARACTERS	LAMINATE THICKNESS (IN)	LAMINATE WIDTH (IN)	INITIAL DRY LAMINATE WEIGHT (GRAM)	INITIAL DRY SPECIMEN WEIGHT (GRAM)	EXPOSED SPECIMEN WEIGHT (GRAM)	FINAL DRY SPECIMEN WEIGHT (GRAM)	ULTIMATE FAILURE LOAD (POUND)	TEST TEMPERATURE (F)
ASEDN01 1	.0978	.2499	1.3324	1.4913	1.5005		443.00	72.0
ASEDN01 2	.1015	.2489	1.3831	1.5477	1.5567		366.00	180.0
AFLDN01 1	.0668	.4923	1.7658	2.0132	2.0256		149.50	72.0
AFLDN01 2	.0647	.4968	1.7431	1.9907	2.0022		145.00	72.0
AFLDN01 3	.0650	.4969	1.7582	2.0009	2.0143		136.00	72.0
AFLDN01 4	.0663	.5004	1.7847	2.0241	2.0355		127.25	180.0
AFLDN01 5	.0659	.4970	1.7899	2.0034	2.0160		127.50	180.0
AFLDN01 6	.0673	.5005	1.7855	2.0342	2.0467		123.50	180.0
AT4DN01 1	.0445	1.0008		25.2045	25.2615		1120.00	180.0
AT4DN01 2	.0449	1.0024		25.0762	25.1322		1080.00	180.0
AT4DN01 3	.0453	1.0003		25.0379	25.1046		1090.00	180.0
ACODN01 1	.1018	.2524					5450.00	72.0
ACODN01 2	.1018	.2433					6230.00	72.0
ACODN01 3	.1025	.2512					6150.00	72.0
ACODN01 4	.1040	.2415					2830.00	180.0
ACODN01 5	.0995	.2467					3660.00	180.0
ACODN01 6	.1004	.2488					2980.00	180.0
BSEDN01 1	.1025	.2480	1.3700	1.5139	1.5205		390.00	72.0
BSEDN01 2	.1033	.2512	1.4265	1.5774	1.5840		232.00	180.0
BFLDN01 1	.0632	.4956	1.6468	1.9050	1.9125		131.20	72.0
BFLDN01 2	.0636	.4956	1.6571	1.9191	1.9269		132.00	72.0
BFLDN01 3	.0633	.4912	1.6290	1.8656	1.8729		112.20	72.0
BFLDN01 4	.0630	.4960	1.6684	1.9108	1.9182		89.00	180.0
BFLDN01 5	.0630	.4953	1.6555	1.8990	1.9072		81.00	180.0
BFLDN01 6	.0636	.4990	1.6698	1.9202	1.9282		85.20	180.0
BT4DN01 1	.0465	1.0013		25.9799	26.0250		1012.00	180.0
BT4DN01 2	.0460	.9982		25.2331	25.2773		1010.00	180.0
BT4DN01 3	.0460	1.0020		25.6028	25.6457		1090.00	180.0
BCODN01 1	.1016	.2510					6130.00	72.0
BCODN01 2	.1032	.2496					5900.00	72.0
BCODN01 3	.1001	.2509					6160.00	72.0
BCODN01 4	.1041	.2493					3860.00	180.0
BCODN01 5	.1031	.2510					3560.00	180.0
BCODN01 6	.1052	.2509					3560.00	180.0
CSEDN01 1	.1090	.2494	1.4921	1.6330	1.6433		490.00	72.0
CSEDN01 2	.1096	.2505	1.5088	1.6448	1.6564		336.00	180.0
CFLDN01 1	.0699	.4984	1.7327	1.9756	1.9865		140.80	72.0
CFLDN01 2	.0674	.4976	1.8104	2.0522	2.0639		153.20	72.0
CFLDN01 3	.0670	.4998	1.8116	2.0580	2.0694		147.00	72.0
CFLDN01 4	.0650	.4997	1.7482	1.9933	2.0049		122.50	180.0
CFLDN01 5	.0644	.4998	1.7437	1.9895	1.9805		113.50	180.0
CFLDN01 6	.0661	.4966	1.7825	2.0062	2.0174		130.80	180.0
CT4DN01 1	.0450	1.0037		25.0586	25.1214		1110.00	180.0
CT4DN01 2	.0464	1.0018		25.1548	25.2186		1150.00	180.0
CT4DN01 3	.0449	1.0005		25.1783	25.2432		1070.00	180.0
CCODN01 1	.1068	.2539					6350.00	72.0
CCODN01 2	.0990	.2493					6250.00	72.0
CCODN01 3	.0984	.2496					6670.00	72.0
CCODN01 4	.1042	.2501					4880.00	180.0
CCODN01 5	.1038	.2508					4840.00	180.0
CCODN01 6	.1084	.2518					5820.00	180.0

Table 5-6 Physical and Mechanical Test Results, Air New Zealand 1 Year Solar Specimens

IDENTIFYING CHARACTERS		LAMINATE THICKNESS (IN)	LAMINATE WIDTH (IN)	INITIAL DRY LAMINATE WEIGHT (GRAM)	INITIAL DRY SPECIMEN WEIGHT (GRAM)	EXPOSED SPECIMEN WEIGHT (GRAM)	FINAL DRY SPECIMEN WEIGHT (GRAM)	ULTIMATE FAILURE LOAD (POUND)	TEST TEMPERATURE (F)
ASEFS01	1	.0973	.2456	1.3183	1.4545	1.4629		463.00	72.0
ASEFS01	2	.0950	.2513	1.3092	1.4651	1.4735		366.00	180.0
AFLFS01	1	.0665	.4994	1.7793	2.0277	2.0420		142.75	72.0
AFLFS01	2	.0660	.5004	1.7578	1.9990	2.0112		136.75	72.0
AFLFS01	3	.0661	.4971	1.7766	2.0140	2.0261		155.00	72.0
AFLFS01	4	.0656	.4969	1.7549	1.9918	2.0051		112.75	180.0
AFLFS01	5	.0660	.4946	1.7569	1.9904	2.0034		128.50	180.0
AFLFS01	6	.0667	.4959	1.7771	2.0103	2.0232		130.25	180.0
AT4FS01	1	.0452	1.0029	9.7454	11.6129	11.6279		1130.00	180.0
AT4FS01	2	.0450	1.0003	9.6731	11.5532	11.5739		1065.00	180.0
BSEFS01	1	.1010	.2453	1.3364	1.4866	1.4940		382.00	72.0
BSEFS01	2	.1051	.2437	1.3927	1.5362	1.5452		230.00	180.0
BFLFS01	1	.0628	.4930	1.6473	1.8640	1.8703		127.20	72.0
BFLFS01	2	.0632	.4985	1.6719	1.9055	1.9127		130.20	72.0
BFLFS01	3	.0630	.4940	1.6888	1.9272	1.9340		128.20	72.0
BFLFS01	4	.0634	.4943	1.6696	1.8857	1.8918		91.20	180.0
BFLFS01	5	.0638	.4935	1.6672	1.9120	1.9192		87.20	180.0
BFLFS0	6	.0645	.4975	1.6848	1.9221	1.9297		86.50	180.0
CSEFS01		.1059	.2490	1.4347	1.5894	1.5994		490.00	72.0
CSEFS01	2	.1106	.2497	1.5048	1.6582	1.6671		358.00	180.0
CFLFS01	1	.0644	.4992	1.7372	1.9507	1.9611		134.50	72.0
CFLFS01	2	.0665	.4996	1.8091	2.0364	2.0476		161.80	72.0
CFLFS01	3	.0632	.4938	1.6858	1.8997	1.9094		136.00	72.0
CFLFS01	4	.0676	.4986	1.8200	2.0364	2.0473		128.20	180.0
CFLFS01	5	.0653	.4998	1.7602	1.9741	1.9844		125.00	180.0
CFLFS01	6	.0668	.5004	1.8095	2.0269	2.0369		136.00	180.0
CT4FS01	1	.0462	1.0021	9.7865	11.2009	11.2561		1250.00	180.0
CT4FS01	2	.0460	1.0030	9.8959	11.3929	11.4483		1250.00	180.0

Table 5-7 Physical and Mechanical Test Results, Air New Zealand 1 Year Non-Solar Specimens

IDENTIFYING CHARACTERS	LAMINATE THICKNESS (IN)	LAMINATE WIDTH (IN)	INITIAL DRY LAMINATE WEIGHT (GRAM)	INITIAL DRY SPECIMEN WEIGHT (GRAM)	EXPOSED SPECIMEN WEIGHT (GRAM)	FINAL DRY SPECIMEN WEIGHT (GRAM)	ULTIMATE FAILURE LOAD (POUND)	TEST TEMPERATURE (F)
ASEFN01 1	.0968	.2488	1.3221	1.4719	1.4807		455.00	72.0
ASEFN01 2	.0932	.2486	1.2823	1.4287	1.4372		339.00	180.0
AFLFN01 1	.0658	.4953	1.7392	1.9699	1.9834		142.00	72.0
AFLFN01 2	.0652	.4972	1.7521	1.9745	1.9857		143.75	72.0
AFLFN01 3	.0659	.4963	1.7668	1.9950	2.0074		145.25	72.0
AFLFN01 4	.0658	.4987	1.7704	2.0004	2.0145		135.25	180.0
AFLFN01 5	.0653	.4969	1.7683	2.0025	2.0180		126.50	180.0
AFLFN01 6	.0665	.4970	1.7829	2.0191	2.0312		133.75	180.0
AT4FN01 1	.0449	1.0005	9.5628	10.4117	10.4760		1020.00	180.0
AT4FN01 2	.0453	1.0003	9.6690	10.5367	10.6055		985.00	180.0
BSEFN01 1	.1006	.2431	1.3624	1.4492	1.4583		389.00	72.0
BSEFN01 2	.1020	.2454	1.3703	1.5317	1.5372		227.00	180.0
BFLFN01 1	.0632	.4958	1.6711	1.9703	1.9766		138.00	72.0
BFLFN01 2	.0635	.4953	1.6613	1.9448	1.9504		135.20	72.0
BFLFN01 3	.0636	.4955	1.6699	1.9564	1.9621		127.50	72.0
BFLFN01 4	.0628	.4990	1.6638	1.9320	1.9360		111.50	180.0
BFLFN01 5	.0630	.4960	1.7004	1.9923	1.9980		104.80	180.0
BFLFN01 6	.0638	.4950	1.6603	1.9418	1.9474		106.20	180.0
CSEFN01 1	.1119	.2499	1.5173	1.6492	1.6578		506.00	72.0
CSEFN01 2	.1119	.2498	1.5273	1.6597	1.6995		354.00	180.0
CFLFN01 1	.0678	.4983	1.8281	2.0734	2.0835		147.50	72.0
CFLFN01 2	.0644	.4972	1.7390	1.9800	1.9884		136.00	72.0
CFLFN01 3	.0673	.4990	1.8180	2.0481	2.0574		160.50	72.0
CFLFN01 4	.0678	.4993	1.8375	2.0655	2.0771		143.00	180.0
CFLFN01 5	.0649	.4996	1.7559	1.9761	1.9857		117.00	180.0
CFLFN01 6	.0678	.4997	1.8259	2.0494	2.0602		137.50	180.0
CT4FN01 1	.0479	.9978	10.2423	11.3913	11.4525		1240.00	180.0
CT4FN01 2	.0478	1.0015	10.0419	11.2139	11.2821		1245.00	180.0

Table 5-8 Physical and Mechanical Test Results, Air New Zealand 1 Year Interior Specimens

IDENTIFYING CHARACTERS	LAMINATE THICKNESS (IN)	LAMINATE WIDTH (IN)	INITIAL DRY LAMINATE WEIGHT (GRAM)	INITIAL DRY SPECIMEN WEIGHT (GRAM)	EXPOSED SPECIMEN WEIGHT (GRAM)	FINAL DRY SPECIMEN WEIGHT (GRAM)	ULTIMATE FAILURE LOAD (POUND)	TEST TEMPERATURE (F)
ASEF101 1	.1067	.2480	1.4217	1.5675	1.5739		529.00	72.0
ASEF101 2	.0984	.2502	1.3340	1.4841	1.4907		308.00	180.0
AFLF101 1	.0650	.4973	1.7866	1.9753	1.9854		149.00	72.0
AFLF101 2	.0665	.4975	1.7797	1.9869	1.9978		146.75	72.0
AFLF101 3	.0659	.4951	1.7547	1.9762	1.9857		144.75	72.0
AFLF101 4	.0658	.4926	1.7544	1.9726	1.9831		132.50	180.0
AFLF101 5	.0667	.4960	1.7839	1.9969	2.0053		135.50	180.0
AFLF101 6	.0652	.4935	1.7155	1.9422	1.9518		109.20	180.0
AT4F101 1	.0419	1.0016	8.9172	10.5725	10.5979		1115.00	72.0
AT4F101 2	.0418	1.0000	8.9802	10.6979	10.4809		1160.00	72.0
AT4F101 3	.0423	1.0009	9.0206	10.6673	10.5480		1170.00	72.0
AT4F101 4	.0450	1.0031	9.5801	10.4508	10.5150		985.00	180.0
AT4F101 5	.0449	1.0015	9.6402	10.4936	10.6958		865.00	180.0
AT4F101 6	.0449	.9996	9.5394	10.4152	10.7163		846.00	180.0
AT4F101 7	.0449	1.0027		24.8765	24.9384		1030.00	180.0
AT4F101 8	.0445	1.0038		24.7883	24.8427		972.00	180.0
AT4F101 9	.0444	1.0033		24.7429	24.7984		875.00	180.0
ACOF101 1	.1004	.2495					6080.00	72.0
ACOF101 2	.1080	.2470					5790.00	72.0
ACOF101 3	.1038	.2465					5210.00	72.0
ACOF101 4	.1030	.2438					3170.00	180.0
ACOF101 5	.1024	.2506					3660.00	180.0
ACOF101 6	.1048	.2493					3760.00	180.0
BSEF101 1	.1029	.2441	1.3624	1.4861	1.4924		455.00	72.0
BSEF101 2	.1038	.2438	1.3726	1.5213	1.5254		223.00	180.0
BFLF101 1	.0630	.4989	1.6669	1.9518	1.9558		138.50	72.0
BFLF101 2	.0641	.4932	1.6666	1.9474	1.9535		135.50	72.0
BFLF101 3	.0630	.4920	1.6498	1.9289	1.9327		132.80	72.0
BFLF101 4	.0628	.4975	1.6673	1.9404	1.9451		104.70	180.0
BFLF101 5	.0640	.4945	1.6646	1.9231	1.9282		108.50	130.0
BFLF101 6	.0630	.4970	1.6716	1.9455	1.9512		98.00	180.0
BT4F101 1	.0437	1.0009	9.2822	10.6750	10.7168		1335.00	72.0
BT4F101 2	.0439	1.0030	9.2908	10.6948	10.7328		1380.00	72.0
BT4F101 3	.0442	1.0041	9.3153	10.6939	10.7311		1280.00	72.0
BT4F101 4	.0442	1.0020	9.1555	10.5292	10.5740		1030.00	180.0
BT4F101 5	.0433	1.0044	9.2096	10.5897	10.6237		820.00	180.0
BT4F101 6	.0437	.9993	9.2897	10.5954	10.6371		980.00	180.0
BT4F101 7	.0430	1.0022		24.4964	24.5382		970.00	180.0
BT4F101 8	.0427	1.0013		24.5117	24.5537		990.00	180.0
BT4F101 9	.0429	1.0022		24.4017	24.4425		950.00	180.0
BCOF101 1	.1016	.2497					6160.00	72.0
BCOF101 2	.1009	.2465					6280.00	72.0
BCOF101 3	.1046	.2498					6180.00	72.0
BCOF101 4	.1033	.2517					3880.00	180.0
BCOF101 5	.1105	.2510					4590.00	180.0
BCOF101 6	.1030	.2469					3950.00	180.0

Table 5-8 Physical and Mechanical Test Results, Air New Zealand 1 Year Interior Specimens (Concluded)

IDENTIFYING CHARACTERS		LAMINATE THICKNESS (IN)	LAMINATE WIDTH (IN)	INITIAL DRY LAMINATE WEIGHT (GRAM)	INITIAL DRY SPECIMEN WEIGHT (GRAM)	EXPOSED SPECIMEN WEIGHT (GRAM)	FINAL DRY SPECIMEN WEIGHT (GRAM)	ULTIMATE FAILURE LOAD (POUND)	TEST TEMPERATURE (F)
CSEF101	1	.1100	.2499	1.4934	1.6355	1.6431		534.00	72.0
CSEF101	2	.1102	.2492	1.4908	1.6726	1.6812		357.00	180.0
CFLF101	1	.0683	.5018	1.8304	2.0822	2.0718		159.80	72.0
CFLF101	2	.0671	.4981	1.7789	2.0039	2.0153		154.50	72.0
CFLF101	3	.0687	.5006	1.7851	2.0188	2.0282		145.50	72.0
CFLF101	4	.0682	.5007	1.8311	2.0705	2.0805		145.20	180.0
CFLF101	5	.0681	.4987	1.7580	2.0209	2.0306		120.20	180.0
CFLF101	6	.0684	.5009	1.8264	2.0588	2.0682		129.20	180.0
CT4F101	1	.0440	1.0040	9.8821	11.2762	11.3270		1260.00	72.0
CT4F101	2	.0443	1.0035	9.8189	11.2280	11.2852		1280.00	72.0
CT4F101	3	.0455	1.0020	9.8366	11.2835	11.3407		1300.00	72.0
CT4F101	4	.0465	1.0015	9.9779	11.4039	11.4597		1250.00	180.0
CT4F101	5	.0470	1.0019	10.1313	11.6205	11.6795		1220.00	180.0
CT4F101	6	.0446	1.0032	9.7421	11.2175	11.2766		1160.00	180.0
CT4F101	7	.0463	1.0008		25.1106	25.1761		1140.00	180.0
CT4F101	8	.0458	.9991		25.2666	25.3248		1130.00	180.0
CT4F101	9	.0450	1.0005		25.2962	25.3478		1080.00	180.0
CC0F101	1	.1041	.2516					5710.00	72.0
CC0F101	2	.1033	.2516					6530.00	72.0
CC0F101	3	.1031	.2523					6770.00	72.0
CC0F101	4	.1078	.2532					4980.00	180.0
CC0F101	5	.1014	.2506					4720.00	180.0
CC0F101	6	.1049	.2501					4200.00	180.0

Table 5-9. Results Summary, Dryden Nominal 2 Year Solar Specimens

PROPERTY	SPECIMEN CONFIGURATION	MATERIAL SYSTEM		
		5208	5209	934
Room Temperature Residual Strength Data (% of Baseline)**	SBS Flexure ±45 Tension	101.4 107.8 111.9†	94.4 111.1 112.7	93.4 100.2 109.1
Elevated Temperature Residual Strength data (% of Baseline)**	SBS Flexure ±45 Tension	104.6 108.4 97.0	87.2 92.6 93.5	86.0 102.7 97.0
Weight Change Data Percent Gain + Percent Loss -	SBS Flexure ±45 Tension	+0.0069 -0.3282 -0.3181	+0.0101 -0.2471 -0.2283	+0.0733 -0.2471 -0.2230

†Average of two measurements

Notes:

* These specimens exposed for 715 days.
** Residual strength data base on baseline tests at the respective temperatures.

Table 5-10. Results Summary, Dryden Nominal 2 Year Non Solar Specimens*

PROPERTY	SPECIMEN CONFIGURATION	MATERIAL SYSTEM		
		5208	5209	934
Room Temperature Residual Strength Data (% of Baseline)**	SBS Flexure	91.7 102.3	95.2 106.9	94.6 102.0
Elevated Temperature Residual Strength Data (% of Baseline)**	SBS Flexure Stressed Tension	99.4 112.3 106.8	86.3 103.5 89.5	86.0 106.4 108.3
Weight Change Data Percent Gain + Percent Loss -	SBS Flexure Stressed	+0.1122 -0.4743 -0.0089	-0.0064 -0.2587 -0.2274	+0.1091 -0.1844 -0.0474

Notes:

* These specimens exposed for 715 days.

** Residual strength data base on baseline tests at the respective temperatures.

Table 5-11. Results Summary, Wellington, New Zealand 1 Year Solar Specimens*

PROPERTY	SPECIMEN CONFIGURATION	MATERIAL SYSTEM		
		5208	5209	934
Room Temperature Residual Strength Data (% of Baseline)**	SBS Flexure ±45 Tension	94.2 102.8 112.2	87.9 100.7 118.5	90.8 104.7 118.4
Elevated Temperature Residual Strength data (% of Baseline)**	SBS Flexure ±45 Tension	81.8 101.6 118.7	67.0 78.2 88.1	74.6 91.1 109.5
Weight Change Data Percent Gain + Percent Loss -	SBS Flexure ±45 Tension	.65 .68 .64	.39 .38 .39	.51 .56 .49

Notes:

* These specimens exposed for 508 days.

** Residual strength data base on baseline tests at the respective temperatures.

Table 5-12. Results Summary, Wellington, New Zealand 1 Year Non Solar Specimens*

PROPERTY	SPECIMEN CONFIGURATION	MATERIAL SYSTEM		
		5208	5209	934
Room Temperature Residual Strength Data (% of Baseline)**	SBS Flexure	86.6 106.2	87.0 98.9	87.8 93.8
Elevated Temperature Residual Strength Data (% of Baseline)**	SBS Flexure Stressed ±45 Tension	88.1 96.8 125.4	69.9 78.9 87.0	73.4 92.5 105.7
Weight Change Data Percent Gain + Percent Loss -	SBS Flexure Stressed ±45 Tension	.60 .61 .57	.43 .40 .42	.67 .56 .61

Notes:

* These specimens exposed for 507 days.

** Residual strength data base on baseline tests at the respective temperatures.

Table 5-13. Results Summary, Air New Zealand 1 Year Solar Specimens*

PROPERTY	SPECIMEN CONFIGURATION	MATERIAL SYSTEM		
		5208	5209	934
Room Temperature Residual Strength Data (% of Baseline)**	SBS Flexure	92.6 104.2	87.4 102.2	90.6 101.7
Elevated Temperature Residual Strength Data (% of Baseline)**	SBS Flexure ±45 Tension	93.2 96.8 124.8	73.1 80.4 -	77.7 93.9 117.3
Weight Change Data Percent Gain + Percent Loss -	SBS Flexure Stressed ±45 Tension	.58 .65 .15	.54 .36 -	.58 .52 .49

Notes:

* These specimens exposed for 516 days, 2681 flight hours.

** Residual strength data base on baseline tests at the respective temperatures.

Tables 5-14. Results Summary, Air New Zealand 1 Year Non Solar Specimen*

PROPERTY	SPECIMEN CONFIGURATION	MATERIAL SYSTEM		
		5208	5209	934
Room Temperature Residual Strength Data (% of Baseline)**	SBS Flexure	90.3 105.7	85.6 104.7	88.2 98.8
Elevated Temperature Residual Strength Data (% of Baseline)**	SBS Flexure ±45 Tension	89.0 103.4 114.2	73.8 99.7 -	75.9 94.9 112.6
Weight Change Data Percent Gain + Percent Loss -	SBS Flexure ±45 Tension	.60 .66 .64	.36 .28 -	.55 .49 .57

Notes:

* These specimens exposed for 516 days, 2681 flight hours.

** Residual strength data base on baseline tests at the respective temperatures.

Table 5-15. Results Summary, Air New Zealand 1 Year Interior Specimen.*

PROPERTY	SPECIMEN CONFIGURATION	MATERIAL SYSTEM		
		5208	5209	934
Room Temperature Residual Strength Data (% of Baseline)**	SBS Flexure ±45 Tension	95.5 107.4 118.9	102.8 106.7 120.5	94.7 101.5 123.4
Elevated Temperature Residual Strength Data (% of Baseline)**	SBS Flexure +45 Tension Stressed ±45 Tension	76.1 99.1 102.6 110.1	71.7 96.4 83.3 87.4	77.9 90.5 113.7 105.9
Weight Change Data Percent Gain + Percent Loss -	SBS Flexure Tension Stressed ±45 Tension	.43 .50 .41 .55	.35 .25 .37 .40	.49 .49 .50 .56

Notes:

* These specimens exposed for 516 days, 2681 flight hours.

** Residual strength data base on baseline tests at the respective temperatures.

5.2 LABORATORY EXPOSURE AND TESTING

5.2.1 WEATHEROMETER TESTING

Results for the one year exposure Weatherometer flexure specimens are presented in Table 5-16. Residual strength measurements were made at 180°F for all three materials and at room temperature for T300/5208. The room temperature testing shows a five percent strength decrease for the unpainted specimens and a ten percent decrease for the painted specimens. The 180°F testing shows no appreciable strength decrease or strength increase except for the unpainted T300/5208 which decreased about seven percent. No clear trends are discernible from the results at this time since the specimen types showing strength reductions after 6 months exposure were not the same as the specimen types showing strength reductions after one year exposure. The residual glass transition temperatures (Tg) experienced a 15°F decrease for 5208, a 16°F decrease for 5209, and a 16°F decrease for 934. Some trends may be emerging here as Tgs for the 350°F cure systems are showing a steady decrease from 6 month testing. The 250°F cure system (5209), however, showed a slight increase after 6 month Weatherometer exposure. Trends in Tg testing results may show a need for additional concentrated efforts in this area.

5.2.2 TIME ALONE TESTING

In order to provide additional data on time alone exposure effects the specimens originally designated and stored for 10 Year Time Alone exposure were redesigned as 2 Year Time Alone specimens. The actual time period of exposure was measured from the actual date of laminate fabrication and differs slightly for each material type. The specimens were weighed immediately upon removal from their sealed storage containers and submitted to test. Results for the 2 year specimens appear in Table 5-17. Strength and weight change trends for 1 and 2 year specimens are plotted in Figures 5-3, 5-4, and 5-5.

To replace the 10 year Time Along Specimens, specimens which had been fabricated in excess of those originally required were removed from storage, weighed, dimensionally measured, appropriately labeled, and stored in containers partially filled with indicator desicant. The 10 year Time Alone period will be measured from the date of laminate fabrication. The desicant will be replaced from time to time as required.

Time Alone Specimens were also stored in sealed containers for the optional material systems AS1/3501-6 and 49/F161-188.

Table 5-16. Weatherometer 1 Year Nominal Exposure

Residual Flexure Strengths and Glass Transition Temperatures

Material	Strengths, Percent		Glass Transition Temp. (^{o}F)	
	Room Temperature	180^{o}	1 Year	Change from Baseline
5208 Painted	89.9	115.5	398	-19
Unpainted	94.4	92.6	405	-12
5209 Painted	--	117.3	241	-21
Unpainted	--	103.0	250	-12
934 Painted	--	108.7	386	-15
Unpainted	--	99.6	384	-17

Residual strength data reported as a percent of baseline strength at the respective temperatures.

Table 5-17. 2 Year Time Alone Residual Strength and Weight Change Results

	RT	180°	Weight
SBS			
5208	99.6	96.2	-.103
5209	93.6	94.9	-.026
934	96.6	87.3	-.248
Flexure			
5208	96.5	97.7	-.141
5209	97.7	102.2	-.093
934	103.0	98.6	-.222

Residual strength data reported as a percent of baseline strength at the respected temperature.

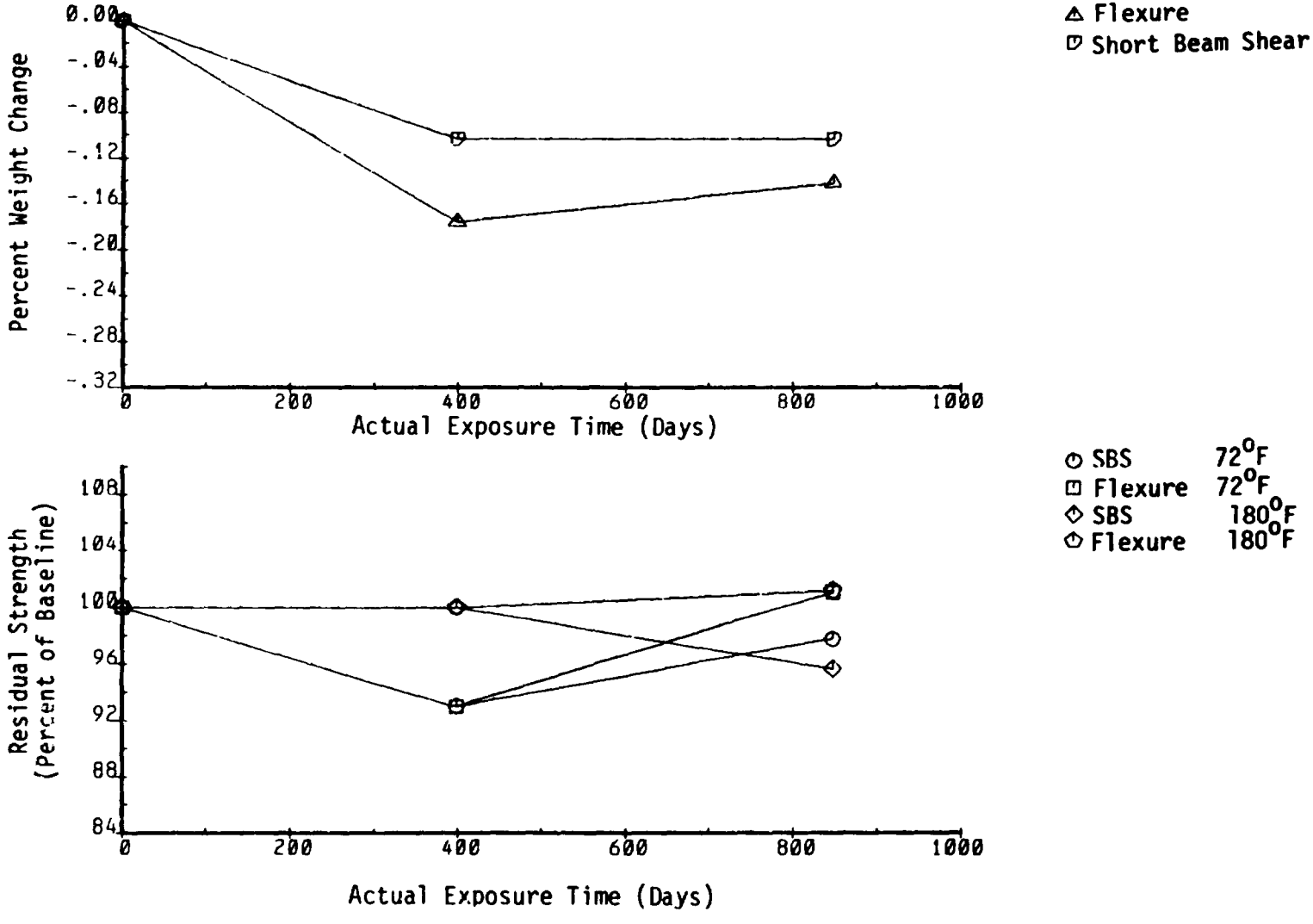

Figure 5-3. Time Alone Strength and Weight Trends for 5208

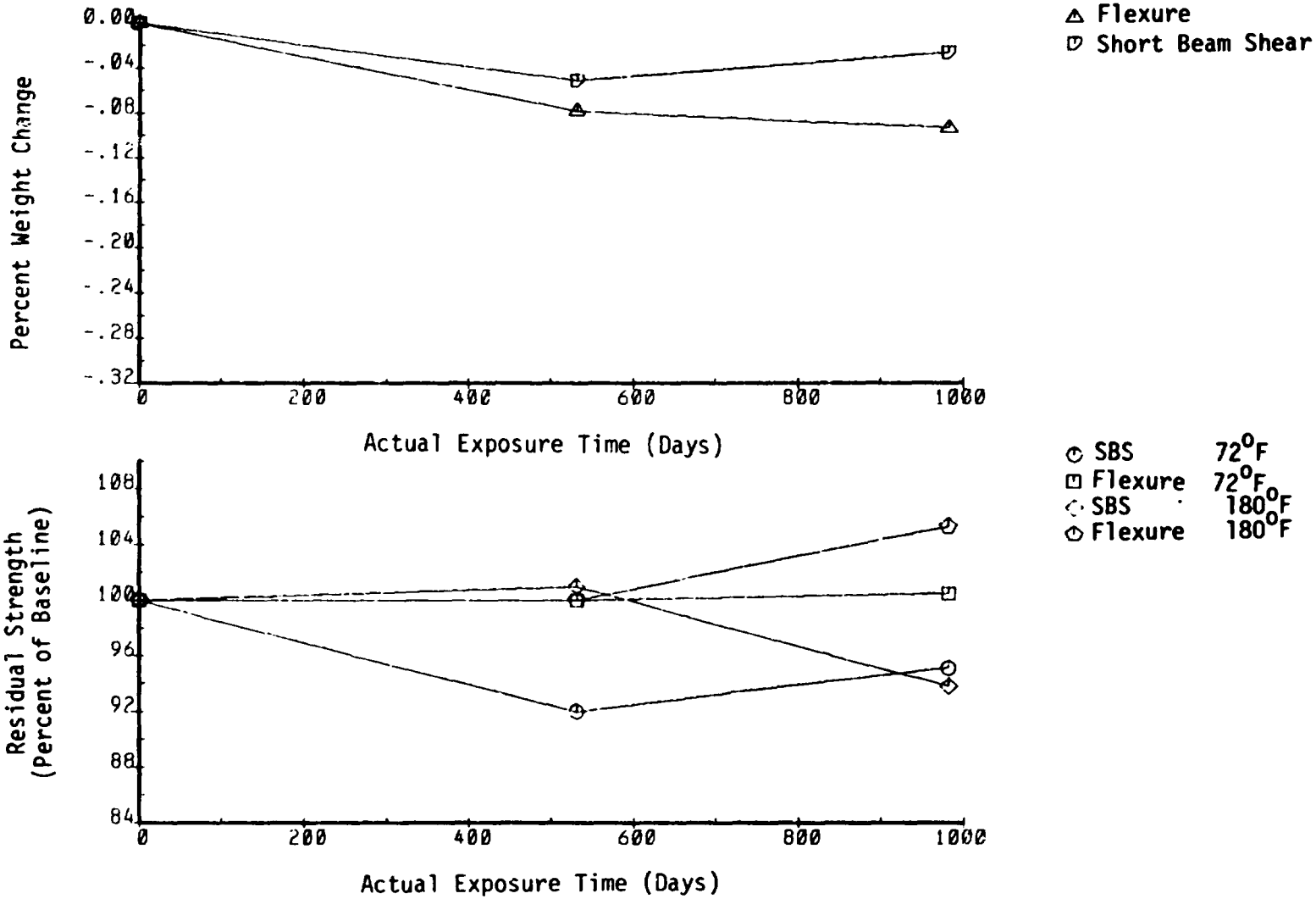

Figure 5-4. Time Alone Strength and Weight Trends for 5209.

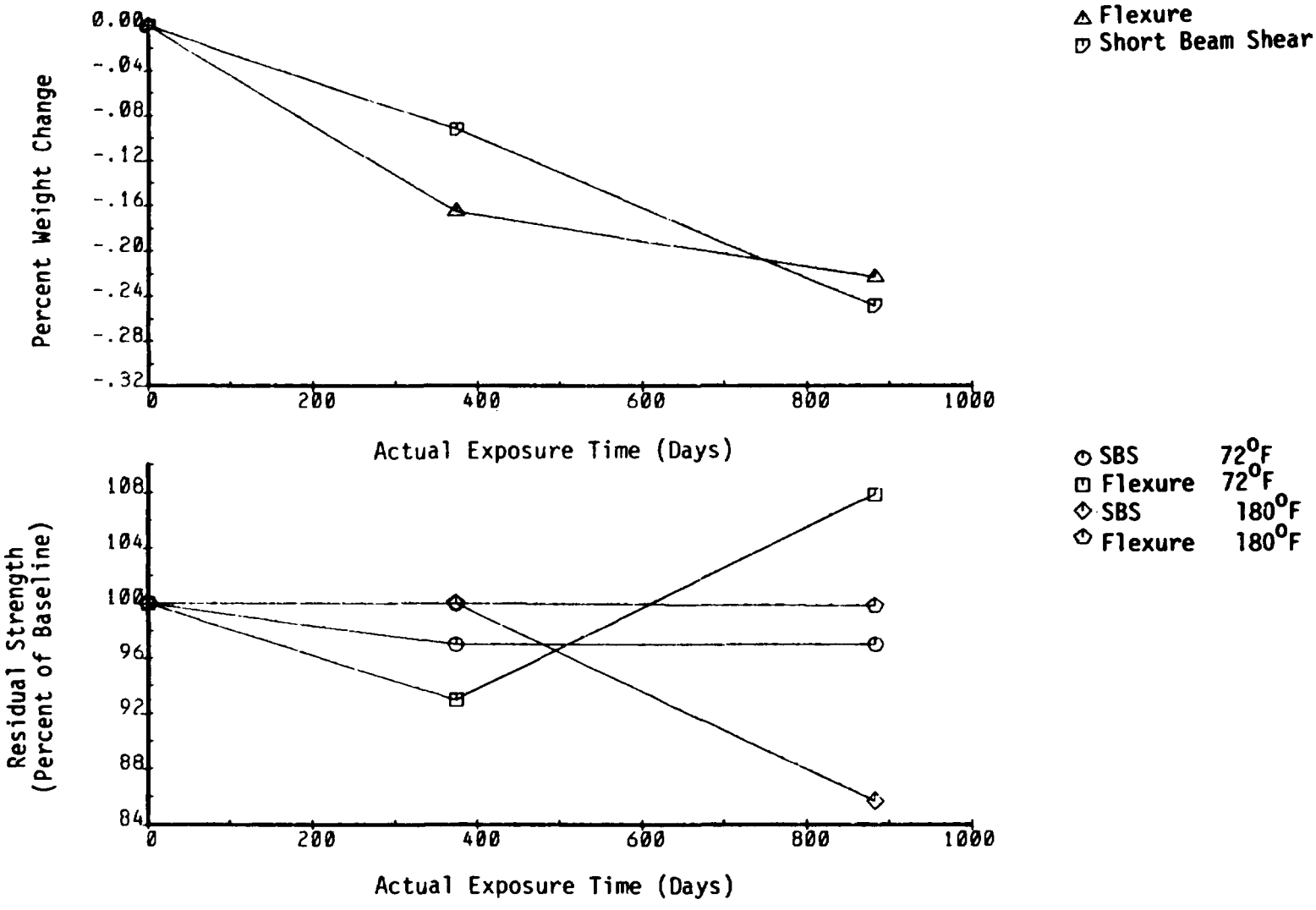

Figure 5-5. Time Alone Strength and Weight Trends for 934.

5.2.3 COMPRESSION TESTING

After the start of the program there was some discussion among NASA and Boeing personnel on the best choice for a compression testing fixture. Two fixtures were under consideration: the Celanese fixture and the IITRI fixture. Testing was performed at Boeing for comparing performance of the two fixtures. Several graphite/epoxy specimens had back-to-back strain gages mounted to the specimen surface. Load/strain curves generated during test showed that the Celanese fixture produced somewhat less bending in the specimen than the IITRI fixture produced. There was also some concern that the alignment pins in the Celanese fixture might be carrying some of the load during test. Therefore, back-to-back strain gages were mounted to the pins, and testing results showed that the pins were supporting no more than 48 lbs of the load at specimen fracture. Finally, since the Boeing material testing labs have access to a Celanese fixture, but not an IITRI fixture, and no particular advantage could be found with the IITRI fixture, the decision was made to use the Celanese fixture for all further compression testing on this contract.

5.2.4 WEBBER CHAMBER

An area of concern that has developed during the course of lab exposure and testing is the performance of the simulated ground-air-ground cycling chamber. Reliability of this facility has been poor, averaging less than 50% for the last several months. This test facility is relatively complex and, as such, is more prone to breakdown than a simple facility such as a humidity cabinet. The original Task III test plans incorporated a range of test facility complexity.

The purpose of the simulated ground-air-ground cycling chamber was to evaluate the freeze thaw cycle experienced by most aircraft during normal operation. When it runs, the chamber is believed to do an effective job simulating this environment. The real problem is not the low efficiency of the chamber but the non-standard environment that the specimens experience when the chamber malfunctions. If a relay sticks on the cold portion of the cycle the specimens may remain "frozen" for one or more days. Since the original 10 minute hold at cold temperatures was arbitrary, injecting a longer hold does not invaliate the test. If a relay sticks at elevated temperatures, the specimens may actually experience temperatures above that seen in service. This may make any subsequent test values invalid.

Testing of one year specimens from Hawaii and from New Zealand did not show an effect due to the freeze thaw experienced by the aircraft specimens when compared to ground rack specimens. Also, the first set of specimens withdrawn from the simulation chamber (Figure 5-18) did not show strength reductions beyond that expected from moisture content alone. Current plans are to test a second set of simulation chamber specimens and then make a decision regarding continued lab testing of this nature.

Table 5-18. 6 Month G-A-G Residual Strength Results

Test Temp.	R.T.	180°F
SBS		
5208	88.4	79.3
5209	79.9	61.7
934	86.1	67.3
Flexure		
5208	80.4	83.4
5209	83.1	72.6
934	87.9	79.9

Residual strength data reported as a percent of baseline strength at the respective temperature.

6.0 REFERENCES

1. "Environmental Exposure Effects on Composite Materials for Commercial Aircraft", NAS1-15148, First Quarterly Progress Report. NASA CR-165641, February 1978.

2. "Environmental Exposure Effects on Composite Materials for Commercial Aircraft", NAS1-15148, Second Quarterly Progress Report. NASA CR-165642, May 1978.

3. "Environmental Exposure Effects on Composite Materials for Commercial Aircraft", NAS1-15148, Third Quarterly Progress Report. NASA CR-165643, August 1978.

4. "Environmental Exposure Effects on Composite Materials for Commercial Aircraft", NAS1-15148, Fourth Quarterly Progress Report. NASA CR-165644, December 1978.

5. "Environmental Exposure Effects on Composite Materials for Commercial Aircraft", NAS1-15148, Fifth Quarterly Progress Report. NASA CR-165645, February 1979.

6. "Environmental Exposure Effects on Composite Materials for Commercial Aircraft", NAS1-15148, Sixth Quarterly Progress Report. NASA CR-165646, May 1979.

7. "Environmental Exposure Effects on Composite Materials for Commercial Aircraft", NAS1-15148, Seventh Quarterly Progress Report. NASA CR-165647, August 1979.

8. "Environmental Exposure Effect on Composite Materials for Commercial Aircraft", NAS1-15148, Eighth Quarterly Progress Report. NASA CR-165648, November 1979.

9. "Environmental Exposure Effect on Composite Materials for Commercial Aircraft", NASA-15148, Ninth Quarterly Progress Report. NASA CR-165649, August 1980.